Four-Mirror Freeform Reflective Imaging Systems

Completed Technology Project (2016 - 2020)

Project Introduction

Central Objectives: The research involves a revelation of the solution space for revolutionary families of four-mirror freeform reflective imaging systems. A freeform optical system is one that lacks rotational symmetry, meaning there is no constraint on the surface shape of the mirrors. Freeform designs can mitigate the disadvantages that prevent reflective systems from being used in larger field of view applications by yielding unobscured designs and leveraging the added freedom of surface shape to better correct the optical aberrations in the system. Freeform designs are made unobscured by breaking the axis of rotational-symmetry and tilting the individual elements themselves. They do not require an offset aperture or field bias, which brings a unique advantage in the correction of optical aberrations. By getting the mirrors out of their own way, more surfaces can be introduced. When compared to alternate solutions, whether it is a rotationally symmetric system or an unobscured system with the same number of elements, an increased diffraction-limited field of view has been demonstrated in our group's research. Methods/Techniques: The exploration of the solution space will be accomplished by expanding upon the work of Andrew Rakich, who derived the analytical solution space for four-mirror anastigmat telescopes. The systems that are yielded from his method have spherical surfaces and an axis of rotational symmetry. These designs will be used as starting points for subsequent freeform designs. Lens design software will be used to optimize the design as the elements are tilted. When tilting elements, very strong astigmatism is introduced. Therefore, toroidal base mirrors for the freeform surfaces are needed for correction. Zernike polynomials are then introduced to the toroidal base shapes to further correct the system. The research aims to explore a variety of targeted research questions that aim to address space technology challenges. The sensitivity of the designs from the solution space to common tolerances will be studied using full-field displays that isolate each aberration and show its dependence over the field, combined with Nodal Aberration Theory that puts tolerances in linear space, making the sensitivity calculation efficient and complete. Special attention will be paid to geometries that may be more conducive to stray light reduction through the use of baffles. Similarly, other geometries may be more conducive to radiation shielding by using the mirror substrates themselves as part of the shielding. The added flexibility of folding geometry allows for the design to be tailored to system engineering constraints that could not be addressed with rotationally symmetric systems or unobscured non-freeform systems. Design approaches to achieve these characteristics will be developed. Significance: This research will address NASA interests as per the July 2015 technology roadmap item TA 8.2.1.3. A key, driving aspect of this work will be to focus on revealing key flat field Large, low cost, lightweight precision monolithic mirrors that provide a high degree of thermal and dynamic stability, and wavefront sensing and control for Ultra-Stable Large-Aperture UV/Visible/Near-IR telescopes. This research is directly relevant to the Observatories level 2 TABS element, 8.2. More specifically, it is relevant to the level 3 TABS element Mirror Systems. The significance of this work is

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to provide imaging system designs with larger diffraction-limited etendues than the state-of-the-art, (meaning larger apertures and fields of view), which will make the most of limited package sizes and mass constraints. This will advance the optical instrumentation on space probes as well as observatories on the ground towards new space discoveries and knowledge.

Anticipated Benefits

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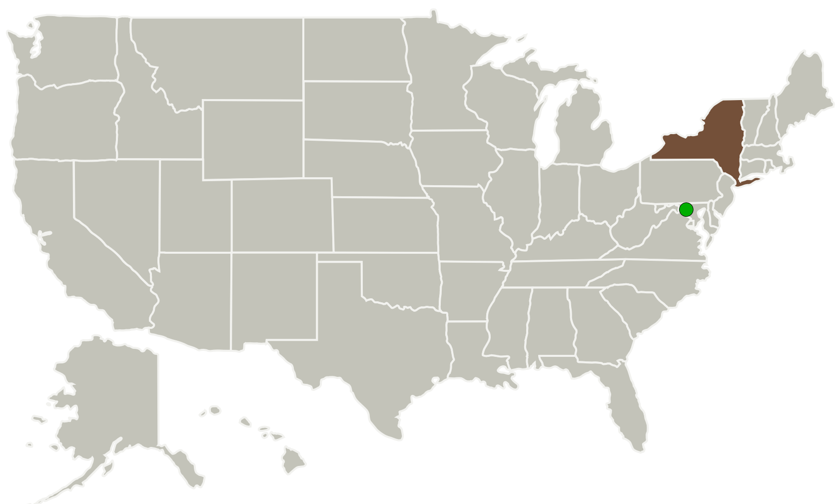
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Rochester	Lead Organization	Academia	Rochester, New York
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Rochester

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Jannick P Rolland

Co-Investigator:

Jonathan Papa

Primary U.S. Work Locations

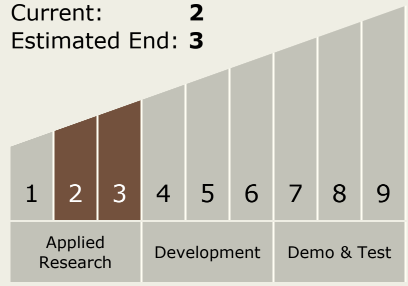
New York

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX14 Thermal Management Systems
  └ TX14.2 Thermal Control Components and Systems
    └ TX14.2.8 Measurement and Control

Target Destinations

Earth, Others Inside the Solar System